National Aeronautics and
Space Administration
Marshall Space Flight Center

Rapid Prototyping of Biological Materials for In-Space Applications

NASA *In Situ* Fabrication and Repair (ISFR)

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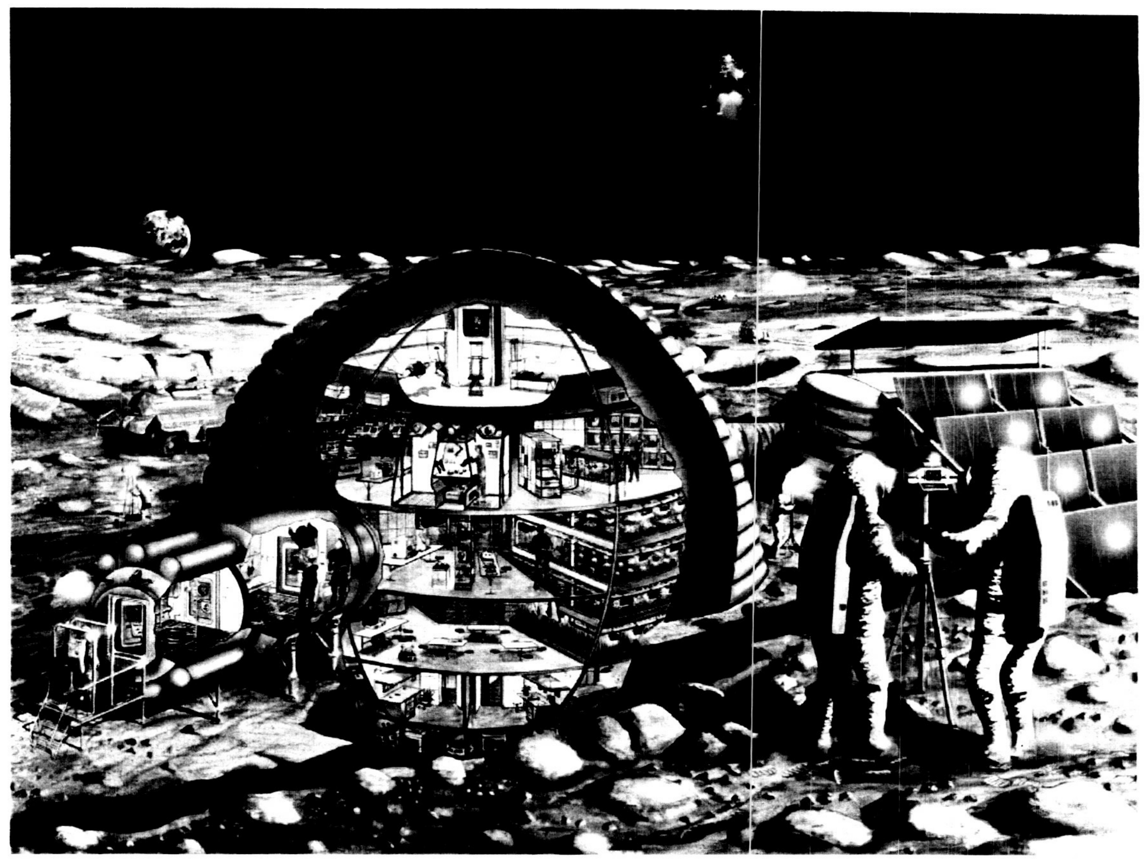
Presentation Outline

- Why is this technology needed?
- In-Situ Fabrication and Repair (ISFR) and In-Situ Resource Utilization (ISRU)
- Multi-Material Fabricator
- Medical Products
- Bioplotter
- Closing Remarks
- Additional Information



Why is This Technology Needed?

- President Bush's Exploration Initiative to return to the Moon and venture to Mars with manned missions
- Longer duration missions without near access to Earth will require increased maintainability of systems
- ***Component degradation and failure is inevitable***
- The Space Architect has identified sparing as a principal issue for reducing the mass required for long duration exploration missions
- ***It would not be practical to carry a complete spare parts and tools inventory, nor would an extensive collection of spares necessarily fulfill every emergency need***
- Fabrication of new tools *in situ* to cover unforeseen needs will significantly mitigate risk
- Fabrication equipment used for components, parts, and tools can be used for biological applications
- Humans living in reduced gravity and harsh environment for extended periods of time
- Additional potential for crew injuries
- As the distance between Mission location and Earth increases, risk increases

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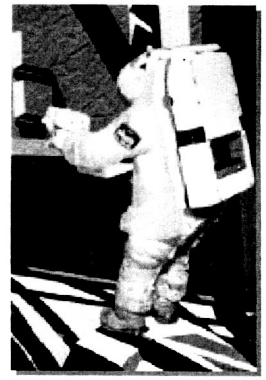
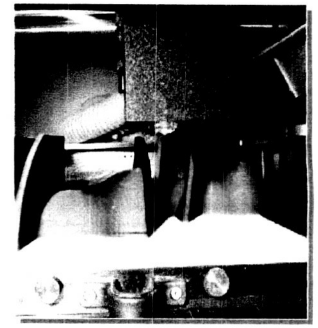
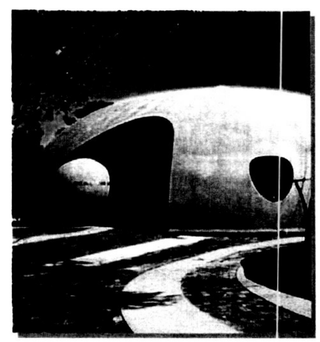
ISFR and ISRU

- In-Situ Fabrication and Repair (ISFR)
  - Fabrication Technologies
    - Medical Products
    - Bioplotter
  - Repair and NDE Technologies
    - Medical Products
  - Habitat Structures
  - Baseline Concept for ISFR uses provisioned resources
  - Utilize ISRU "mined and refined" capability as it matures
- In-Situ Resource Utilization (ISRU)
  - Maximize the use of natural resources through the extraction from and/or transformation of Lunar and Martian regoliths
  - Provide many of the needed ISFR feed-stocks for fabrication processes including
    - Silicon
    - Iron, aluminum, titanium
    - Glass/Ceramics
  - Recycling







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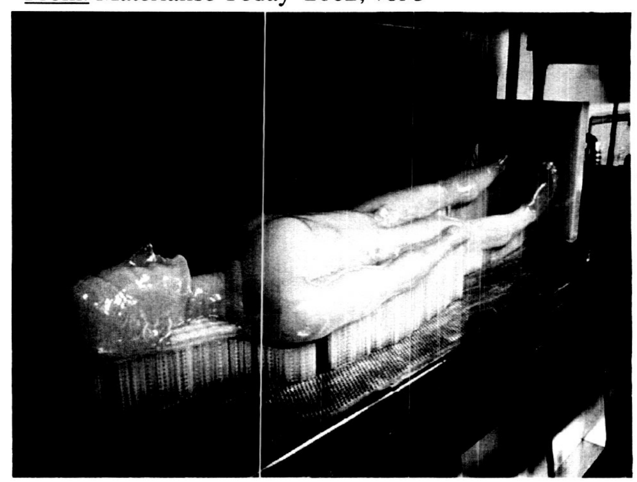
Multi-Material Fabricator

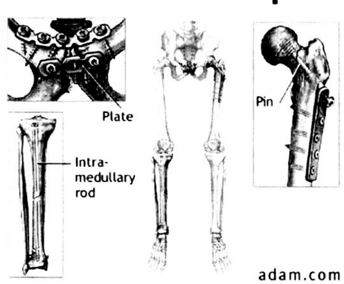
- Multi-Material Fabricator concept comprised of 2 – 3 racks; 1 rack approximately the size of a refrigerator
- Multiple technologies with various ranges of materials processing capability
- Evolving additive techniques for solid freeform fabrication (SFF) rapid prototyping, with focus on multi-material and direct manufacturing
- Wide range of techniques being considered in MSFC Trade Study such as Ultrasonic Object Consolidation (UOC), plasma spray, inkjet printing, and CNC Machining (subtractive technique)
- Feed Stock (e.g., powder, slurries, impregnated filaments, etc.)
- Material capabilities: metals, polymers, ceramics, composites, adhesives
- Key areas of consideration
  - Weight and volume
  - Power
  - Heat generation
  - Operating Environment
  - Reliability
  - Crew Operations

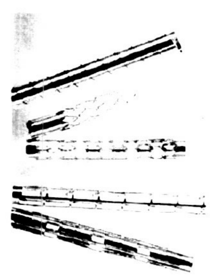
From: Materialise Today 2002, vol 3

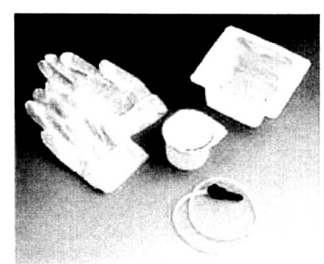


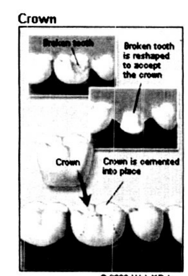
Medical Products

- Target treatment of major and minor injuries
  - Triage for return to Earth
  - Treatment on-site
- Medical Product examples
  - Invasive: pins, plates, stints, catheters, sutures, surgical tools and dental instruments, adhesives for tissue binding and affixing implants
  - Non-invasive: casts, orthodics, tubes, syringes, gloves
  - Dental: fillings, crowns, bridges, dental cement
- Additional capabilities required
  - Sterilization capability
  - Libraries for medical procedures, dental procedures, and medical product specifications



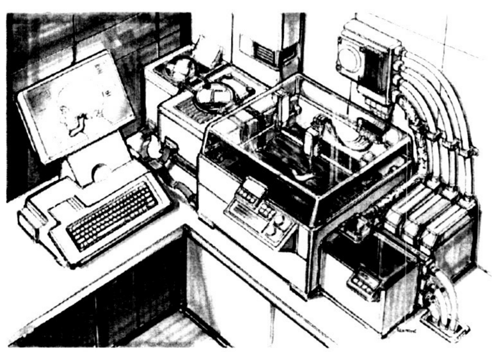




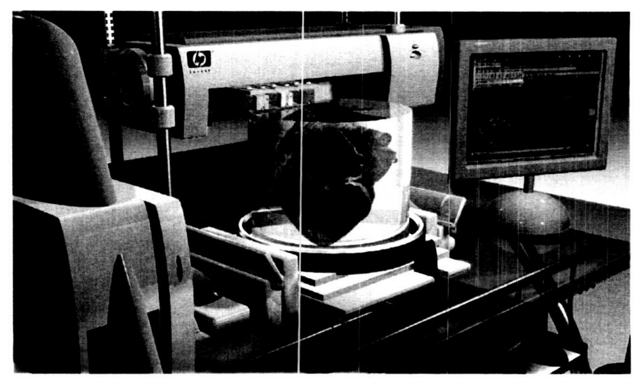


Bioplotter (Tissue Printing)

- Solid Freeform Fabrication (SSF)/Rapid Prototyping (RP) techniques for tissue printing
- Print viable human tissue on hydrogel scaffolds with high throughput, modified COTS inkjet printers
  - Aid in healing process
  - Replace damaged tissue
- Tissue Types
  - Near term capabilities - skin, bone, cartilage, connective tissue and blood vessels
  - Long range capabilities - other smooth muscle, skeletal muscle, and organs
- Potential development and demonstration of a Bioplotter for hypo-g and micro-g



Reference
Dr. Thomas Boland
Clemson University



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Closing Remarks

- Mimic terrestrial treatment capabilities of major and minor injuries in transit to and on extraterrestrial surfaces
  - Evaluate current technology and biomaterials for use in reduced gravity and harsh environment
  - Development of new biocompatible materials that can be made with refined Lunar (oxides, Ti) or Martian (oxides, carbon) Regolith
  - Development of new diagnostic equipment that is miniaturized, multi-functional, and can operate in reduced gravity
- Collaboration between NASA, Science Community, and Industry is essential to mission success

Additional Information

- For more information on NASA's top Exploration concerns, visit the Bioastronautics Roadmap website at: http://bioastroroadmap.nasa.gov/index.jsp
- For more information concerning ISFR, visit the MSFC Exploration Science and Technology Division, In-Situ Fabrication and Repair website at: http://est.msfc.nasa.gov/ISFR/
- The Lunar Sourcebook: A User's Guide to the Moon, G.H. Heiken, D.T. Vaniman, & B.M. French, Eds., 1991, Cambridge University Press (available digitally through Lunar and Planetary Institute, http://www.lpi.usra.edu)
- Mining the Sky, J. S. Lewis, 1996, Perseus Books